Original Investigation

# Associations Between Initial Water Pipe Tobacco Smoking and Snus Use and Subsequent Cigarette Smoking
## Results From a Longitudinal Study of US Adolescents and Young Adults

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**IMPORTANCE** Many adolescents and young adults use alternative tobacco products, such as water pipes and snus, instead of cigarettes.

**OBJECTIVE** To assess whether prior water pipe tobacco smoking and snus use among never smokers are risk factors for subsequent cigarette smoking.

**DESIGN, SETTING, AND PARTICIPANTS** We conducted a 2-wave national longitudinal study in the United States among 2541 individuals aged 15 to 23 years old. At baseline (October 25, 2010, through June 11, 2011), we ascertained whether respondents had smoked cigarettes, smoked water pipe tobacco, or used snus. At the 2-year follow-up (October 27, 2012, through March 31, 2013), we determined whether baseline non–cigarette smokers had subsequently tried cigarette smoking, were current (past 30 days) cigarette smokers, or were high-intensity cigarette smokers. We fit multivariable logistic regression models among baseline non–cigarette smokers to assess whether baseline water pipe tobacco smoking and baseline snus use were associated with subsequent cigarette smoking initiation and current cigarette smoking, accounting for established sociodemographic and behavioral risk factors. We fit similarly specified multivariable ordinal logistic regression models to assess whether baseline water pipe tobacco smoking and baseline snus use were associated with high-intensity cigarette smoking at follow-up.

**EXPOSURES** Water pipe tobacco smoking and the use of snus at baseline.

**MAIN OUTCOMES AND MEASURES** Among baseline non–cigarette smokers, cigarette smoking initiation, current (past 30 days) cigarette smoking at follow-up, and the intensity of cigarette smoking at follow-up.

**RESULTS** Among 1596 respondents, 1048 had never smoked cigarettes at baseline, of whom 71 had smoked water pipe tobacco and 20 had used snus at baseline. At follow-up, accounting for behavioral and sociodemographic risk factors, baseline water pipe tobacco smoking and snus use were independently associated with cigarette smoking initiation (adjusted odds ratios: 2.56; 95% CI, 1.46-4.47 and 3.73; 95% CI, 1.43-9.76, respectively), current cigarette smoking (adjusted odds ratios: 2.48; 95% CI, 1.01-6.06 and 6.19; 95% CI, 1.86-20.56, respectively), and higher intensity of cigarette smoking (adjusted proportional odds ratios: 2.55; 95% CI, 1.48-4.38 and 4.45; 95% CI, 1.75-11.27, respectively).

**CONCLUSIONS AND RELEVANCE** Water pipe tobacco smoking and the use of snus independently predicted the onset of cigarette smoking and current cigarette smoking at follow-up. Comprehensive Food and Drug Administration regulation of these tobacco products may limit their appeal to youth and curb the onset of cigarette smoking.

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The 2009 Family Smoking Prevention and Tobacco Control Act granted regulatory authority to the Food and Drug Administration (FDA) over cigarettes, loose tobacco, and smokeless tobacco products. The FDA does not regulate the manufacture, distribution, and marketing of other tobacco products, such as water pipe tobacco. However, many of these unregulated tobacco products are widely consumed by adolescent and young adult tobacco users.[1,2] For example, adolescents and young adults increasingly smoke water pipe tobacco (also known as hookah) because of its appealing flavor, social and communal experience, and frequent use alongside alcohol.[3,4] In addition, US tobacco companies introduced and aggressively marketed novel smokeless tobacco products, such as snus, in the mid-2000s when clean indoor air laws severely restricted public cigarette smoking.[5,6] Today, novel smokeless tobacco use remains high among some youth subgroups (eg, rural young men).[7]

The increasing use of novel alternative tobacco products introduces new harms to adolescents and young adults. For example, in a single 60-minute water pipe tobacco smoking (WTS) session, smokers inhale approximately 100 times the volume of smoke compared with the smoke inhaled from a single cigarette.[8] Despite the perception that water pipe tobacco smoke is safer than cigarette smoke, the former exposes smokers to greater levels of carbon monoxide and known carcinogens than the latter.[9,10] Novel smokeless tobacco products also pose new potential risks. The high content of unprotonated nicotine in snus may create and sustain nicotine addiction.[11] Furthermore, the use of alternative tobacco products may be even more concerning if it leads to subsequent cigarette smoking, as does the initial use of moist snuff and chewing tobacco.[12-14]

However, few investigations have assessed whether the initial use of alternative tobacco products is associated with subsequent uptake of cigarette smoking among US adolescents and young adults.[15] Fielder et al[16] found that precollege WTS predicted the initiation and resumption of cigarette smoking among US college women, although we do not yet know if this finding holds for adolescents and young adult men. Swedish and US longitudinal investigations yield conflicting results about whether initial snus use increases the risk of subsequent cigarette smoking. Swedish investigators conclude that snus use may be a pathway from, rather than a gateway to, cigarette smoking,[17] while a US-based study[13] found that initial snus use may increase the risk of cigarette smoking.

In this article, we address this research gap and assess whether the use of 2 alternative tobacco products, water pipe tobacco and snus, among non-cigarette smoking adolescents and young adults increases their risk of subsequent cigarette smoking. We hypothesized that WTS and snus use would be associated with increased risk of subsequent cigarette smoking, even after accounting for known sociodemographic and behavioral risk factors.

## Methods

### Data

The Dartmouth Committee for the Protection of Human Subjects approved the study. Oral parental consent and respondent assent were obtained for those younger than 18 years; oral consent was obtained for respondents 18 years or older. Our data come from the first 2 waves of the Dartmouth Media, Advertising, and Health Study.[14] At baseline (October 25, 2010, through June 11, 2011), 3342 individuals 15 to 23 years old were recruited from 6466 eligible households via a random digit-dialing telephone survey using landline (67.0%) and cell phone frames (33.0%). Of 3342 respondents, 2541 also completed a web-based visual survey at baseline. In wave 2 of the study (October 27, 2012, through March 31, 2013), we followed up 2541 respondents who had completed both portions of the baseline survey; 1596 completed the web-based visual survey at wave 2 and received $25 for completion. The weighted screener response rate was 62.8%.[18] We observed differential attrition between waves 1 and 2; older individuals, non-Hispanic blacks, Hispanics, and cigarette smokers were more likely to be lost to follow-up (**Table 1**).

### Outcomes

We examined 3 smoking outcomes at the 2-year follow-up among baseline non-cigarette smokers. These included (1) the initiation of cigarette smoking, (2) current cigarette smoking (within the past 30 days), and (3) the intensity of cigarette smoking. First, a respondent was considered to have initiated cigarette smoking if he or she answered yes to the question, "Have you ever tried smoking a cigarette, even just a puff?" Second, a respondent was considered to be a current smoker if he or she had smoked cigarettes at least 1 day in the past 30 days ("During the past 30 days, on how many days did you smoke cigarettes?"). Third, we created a score of the intensity of cigarette smoking based on respondents' answers to the following 3 questions: (1) "During the past 30 days, on how many days did you smoke cigarettes?" (2) "During the past 30 days, on the days that you smoked, how many cigarettes did you usually smoke per day?" (3) "How many cigarettes have you smoked in your life?" We provide details of the intensity score in eAppendix 1 in the Supplement.

### Covariates

We assessed demographic characteristics of respondents, including their age, sex, race/ethnicity, region, and urbanicity. We assessed respondents' socioeconomic status by maternal educational level and annual parental household income. We assessed whether any of the respondents' friends smoked cigarettes (yes or no) as well as their parental cigarette smoking status (never, former, or current). We classified parental cigarette smoking status to be the more recent of the 2 parents' cigarette smoking status (eAppendix 2 in the Supplement). We also included covariates to address the possibility that users of multiple tobacco products were simply at higher risk of substance use in general. We created a composite measure of sensation seeking based on respondents' answers to 6 personal behavior topics (eg, "I like to do dangerous things" [Cronbach $\alpha = .72$]) and categorized the score into quartiles.[19] To address the possibility that the results were driven by a subset of deviant-prone adolescents and young adults, we controlled for another risky behavior, namely, problem drinking (≥6 drinks per occasion).[20] We considered binge drinking because it is a clinically significant

Table 1. Sample Characteristics Among All Baseline Respondents, Baseline Respondents Without Follow-up, and Baseline Respondents With Follow-up

| Variable | All Baseline Respondents (N = 2541) | Baseline Respondents Without Follow-up (n = 945) | Baseline Respondents With Follow-up (n = 1596) | *P* Value |
|---|---|---|---|---|
| Male sex, % | 48.4 | 49.6 | 47.7 | .38 |
| Age group, % | | | | |
| 15-17 y | 49.6 | 47.3 | 51.0 | .08 |
| 18-20 y | 29.6 | 30.6 | 28.9 | .41 |
| 21-23 y | 20.8 | 22.1 | 20.1 | .23 |
| Race/ethnicity, % | | | | |
| Non-Hispanic white | 69.9 | 63.9 | 73.5 | <.001 |
| Non-Hispanic black | 7.6 | 9.8 | 6.3 | .001 |
| Hispanic | 11.9 | 14.6 | 10.3 | .001 |
| Other | 10.6 | 11.6 | 10.0 | .21 |
| Sensation-seeking quartile, % | | | | |
| 1, Lowest | 34.3 | 33.2 | 35.0 | .40 |
| 2 | 24.2 | 22.1 | 25.5 | .06 |
| 3 | 20.8 | 21.3 | 20.6 | .70 |
| 4, Highest | 20.6 | 23.4 | 19.0 | .009 |
| Friends smoking status, % yes | 64.7 | 69.7 | 61.7 | <.001 |
| Parental smoking status, % | | | | |
| Never | 49.3 | 44.2 | 52.3 | <.001 |
| Former | 21.5 | 22.0 | 21.2 | .70 |
| Current | 29.2 | 33.9 | 26.5 | <.001 |
| Region, % | | | | |
| Midwest | 26.1 | 24.8 | 26.8 | .27 |
| Northeast | 19.0 | 16.3 | 20.7 | .007 |
| South | 31.9 | 34.0 | 30.6 | .08 |
| West | 23.0 | 25.0 | 21.9 | .08 |
| Urbanicity, % | | | | |
| Large rural town | 10.7 | 10.8 | 10.7 | .94 |
| Small town or isolated rural | 12.0 | 14.1 | 10.7 | .01 |
| Suburban | 13.2 | 12.6 | 13.6 | .53 |
| Urban core | 64.0 | 62.4 | 65.0 | .20 |
| Smoked water pipe tobacco, % | 20.1 | 23.5 | 18.1 | .001 |
| Used snus, % | 9.4 | 11.7 | 8.1 | .004 |
| Ever tried cigarette smoking, % | 38.7 | 46.2 | 34.3 | <.001 |
| Current cigarette smoking, % | 15.0 | 20.1 | 12.0 | <.001 |

outcome for youth and is associated with substantial morbidity, mortality, and economic costs.[21-23]

## Statistical Analysis

First, we assessed the proportion of baseline non-cigarette smokers who initiated cigarette smoking by whether they had smoked water pipe tobacco or used snus at baseline. We tested for differences in proportions using Pearson product moment correlation $\chi^2$ test statistic. We conducted a similar assessment and test for baseline snus use. Second, we fit 2 logistic regression models with cigarette smoking initiation at follow-up as the dependent variable and (1) WTS at baseline and (2) snus use at baseline as the respective covariates of interest. Other covariates common to both models included age, sex, race/ethnicity, sensation seeking, friends smoking, parental smoking, binge drinking, maternal education, annual parental household income, region, and urbanicity. Third, we fit 2 similarly specified logistic regression models with current cigarette smoking at follow-up as the dependent variable. Fourth, we conducted factor analysis to create an index for smoking intensity based on the frequency and quantity of current and lifetime smoking (Cronbach α = .78) (eAppendix 1 in the Supplement). We then categorized the smoking intensity index into the following 3 categories: (1) non-cigarette smokers (n = 828), (2) light-intensity cigarette smokers (n = 114, respondents with factor scores less than the median for ciga-

Table 2. Incidence of Cigarette Smoking Initiation and Current Cigarette Smoking at Follow-up by Baseline Water Pipe Tobacco Smoking (WTS) and Snus Use

| Variable | Cigarette Smoking Initiation, No. (%) | | | | Current Cigarette Smoking at Follow-up, No. (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | No | Yes | Total | *P* Value[a] | No | Yes | Total | *P* Value[a] |
| Baseline WTS | | | | | | | | |
| No | 781 (80.1) | 194 (19.9) | **975** (100.0) | <.001 | 928 (95.1) | 48 (4.9) | **976** (100.0) | .04 |
| Yes | 43 (60.6) | 28 (39.4) | **71** (100.0) | | 63 (88.7) | 8 (11.0) | **71** (100.0) | |
| Baseline snus use | | | | | | | | |
| No | 816 (79.5) | 210 (20.5) | **1026** (100.0) | .001 | 976 (95.0) | 51 (5.0) | **1027** (100.0) | .001 |
| Yes | 9 (45.0) | 11 (55.0) | **20** (100.0) | | 15 (75.0) | 5 (25.0) | **20** (100.0) | |

[a] Pearson product moment correlation $\chi^2$ test statistic for equality of proportions, with Yates correction.

rette smokers), and (3) high-intensity cigarette smokers (n = 106, respondents with factor scores at the median or higher). We fit an ordinal logistic regression model with cigarette smoking intensity as the dependent variable and WTS at baseline as the covariate of interest, as well as sociodemographic and behavioral covariates. We fit a similarly specified ordinal logistic regression model with snus use at baseline as the covariate of interest. We provide details of the factor analysis in eAppendix 1 in the Supplement, including an assessment of the proportionality assumption for the models (eTable 1 in the Supplement).

We performed multiple imputation to address missing data for maternal educational level (4.2% missing) and annual parental household income (29.5% missing) (eFigure in the Supplement).[24] Our multiple imputation method assumed that these data were missing at random. We generated 5 multiply imputed data sets, fit the regression models described above, and combined the parameter estimates, accounting for imputation uncertainty. We conducted similarly specified regression analyses based only on fully observed cases (eTable 2 in the Supplement). We used a computer program (R, version 2.9.2; http://cran.r-project.org/bin/windows/base/old/2.9.2/) for all statistical analyses.

We conducted an additional analysis to determine whether the relationship between baseline alternative tobacco product use and subsequent cigarette smoking was specific to tobacco or whether it was also associated with other high-risk behaviors (eg, binge drinking). Specifically, we began with respondents who reported never binge drinking at baseline. We fit multivariable logistic regression models with current binge drinking at follow-up as the dependent variable and WTS and snus use at baseline as the exposure variables, as well as sociodemographic and behavioral covariates.

## Results

### Study Population

Thirty-nine percent of the baseline sample had ever tried cigarette smoking, and 15.0% currently smoked cigarettes (Table 1). In addition, 20.1% of the baseline sample had smoked water pipe tobacco, and 9.4% had used snus. Respondents lost to follow-up were more likely than those not lost to follow-up to have smoked water pipe tobacco (23.5% vs 18.1%, *P* = .001) and have used snus (11.7% vs 8.1%, *P* = .004).

Of 1596 respondents who completed both baseline and follow-up surveys, 1048 (65.7%) had never smoked cigarettes at baseline. Among 1048 baseline non-cigarette smokers, 71 (6.8%) had smoked water pipe tobacco at baseline, and 20 (1.9%) had used snus at baseline. Overall, the incidences of smoking initiation and current smoking were 21.2% and 5.3%, respectively.

Thirty-nine percent of the baseline non-cigarette smokers who had also smoked water pipe tobacco at baseline had initiated cigarette smoking at follow-up compared with 19.9% of those who had not smoked water pipe tobacco (*P* < .001) (**Table 2**). Eleven percent of the baseline non-cigarette smokers who had also smoked water pipe tobacco at baseline were current cigarette smokers at follow-up compared with 4.9% of those who had not smoked water pipe tobacco (*P* = .04). Fifty-five percent of the baseline non-cigarette smokers who had also used snus at baseline had initiated cigarette smoking at follow-up compared with 20.5% of those who had not used snus (*P* = .001). Twenty-five percent of the baseline non-cigarette smokers who had also used snus at baseline were current cigarette smokers at follow-up compared with 5.0% of those who had not used snus (*P* = .001).

### Multivariable Analyses

Adjusting for sociodemographic and behavioral covariates, the odds of cigarette smoking initiation were higher for respondents who had smoked water pipe tobacco at baseline than for those who had not (adjusted odds ratio [aOR], 2.56; 95% CI, 1.46-4.47) (**Table 3**). The adjusted odds of current cigarette smoking at follow-up were also higher for respondents who had smoked water pipe tobacco at baseline than for those who had not (aOR, 2.48; 95% CI, 1.01-6.06). Finally, cigarette smoking intensity was higher for respondents who had smoked water pipe tobacco at baseline than for those who had not (adjusted proportional OR, 2.55; 95% CI, 1.48-4.38) (eTable 3 in the Supplement).

We observed similar findings for baseline snus use. The adjusted odds of cigarette smoking initiation were higher for respondents who had used snus at baseline than for those who had not (aOR, 3.73; 95% CI, 1.43-9.76). The adjusted odds of current cigarette smoking at follow-up were also higher for respondents who had used snus at baseline than for those who had not (aOR, 6.19; 95% CI, 1.86-20.56). Finally, cigarette smoking intensity was higher for respondents who had used snus at baseline than for those who had not (adjusted proportional OR, 4.45; 95% CI, 1.75-11.27).

Table 3. Multivariable Logistic Regression Analyses of Cigarette Smoking Initiation and Current Cigarette Smoking at Follow-up Among Baseline Non–Cigarette Smokers

| Covariate | Model, Adjusted Odds Ratio (95% CI) | | | |
|---|---|---|---|---|
| | 1 Cigarette Smoking Initiation | 2 Current Cigarette Smoking at Follow-up | 3 Cigarette Smoking Initiation | 4 Current Cigarette Smoking at Follow-up |
| Baseline WTS | 2.56 (1.46-4.47) | 2.48 (1.01-6.06) | NA | NA |
| Baseline snus use | NA | NA | 3.73 (1.43-9.76) | 6.19 (1.86-20.56) |
| Age group, y | | | | |
| 15-17 | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| 18-20 | 0.87 (0.59-1.27) | 0.85 (0.43-1.68) | 0.99 (0.68-1.44) | 1.01 (0.51-1.97) |
| 21-23 | 0.67 (0.40-1.11) | 0.78 (0.32-1.93) | 0.72 (0.43-1.19) | 0.78 (0.32-1.93) |
| Sex | | | | |
| Female | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Male | 1.24 (0.89-1.71) | 1.35 (0.76-2.42) | 1.12 (0.81-1.56) | 1.15 (0.63-2.08) |
| Race/ethnicity | | | | |
| Non-Hispanic white | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Non-Hispanic black | 1.82 (0.96-3.45) | 0.86 (0.23-3.21) | 1.87 (0.99-3.53) | 0.91 (0.24-3.40) |
| Hispanic | 1.80 (1.00-3.26) | 1.72 (0.65-4.51) | 1.72 (0.95-3.11) | 1.55 (0.59-4.08) |
| Other | 1.23 (0.71-2.14) | 0.36 (0.08-1.57) | 1.25 (0.72-2.18) | 0.39 (0.09-1.73) |
| Sensation-seeking quartile | | | | |
| 1, Lowest | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| 2 | 1.34 (0.89-2.02) | 1.03 (0.46-2.28) | 1.32 (0.88-2.00) | 0.99 (0.44-2.20) |
| 3 | 1.87 (1.19-2.94) | 1.56 (0.66-3.65) | 1.79 (1.14-2.83) | 1.38 (0.58-3.28) |
| 4, Highest | 2.93 (1.84-4.67) | 3.78 (1.78-8.05) | 2.92 (1.84-4.66) | 3.73 (1.75-7.94) |
| Friends smoking status | | | | |
| No | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Yes | 1.95 (1.39-2.72) | 1.74 (0.94-3.22) | 1.97 (1.41-2.75) | 1.75 (0.94-3.25) |
| Parental smoking status | | | | |
| Never | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Former | 1.33 (0.88-2.01) | 1.35 (0.66-2.77) | 1.40 (0.93-2.11) | 1.43 (0.69-2.97) |
| Current | 1.83 (1.22-2.75) | 1.64 (0.78-3.44) | 1.87 (1.25-2.80) | 1.68 (0.81-3.50) |
| Ever binge drinking | | | | |
| No | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Yes | 1.26 (0.77-2.05) | 1.16 (0.53-2.54) | 1.37 (0.83-2.26) | 1.30 (0.58-2.93) |
| Maternal educational level | | | | |
| <High school | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| High school graduate | 0.62 (0.29-1.33) | 0.99 (0.29-3.40) | 0.57 (0.26-1.25) | 0.89 (0.25-3.10) |
| ≥Some college | 0.42 (0.21-0.86) | 0.43 (0.14-1.34) | 0.42 (0.21-0.86) | 0.40 (0.13-1.25) |
| Annual parental household income, $ | | | | |
| <50 000 | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| 50 000 to <$100 000 | 1.08 (0.72-1.63) | 1.17 (0.50-2.74) | 1.09 (0.72-1.64) | 1.14 (0.49-2.63) |
| ≥100 000 | 1.25 (0.79-1.96) | 1.40 (0.62-3.18) | 1.31 (0.84-2.06) | 1.48 (0.65-3.34) |
| Region | | | | |
| Midwest | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Northeast | 0.82 (0.52-1.30) | 1.21 (0.54-2.74) | 0.88 (0.55-1.39) | 1.35 (0.59-3.08) |
| South | 0.82 (0.54-1.24) | 1.25 (0.60-2.62) | 0.88 (0.58-1.34) | 1.40 (0.66-2.94) |
| West | 0.52 (0.31-0.86) | 0.60 (0.23-1.56) | 0.60 (0.36-0.99) | 0.74 (0.29-1.94) |

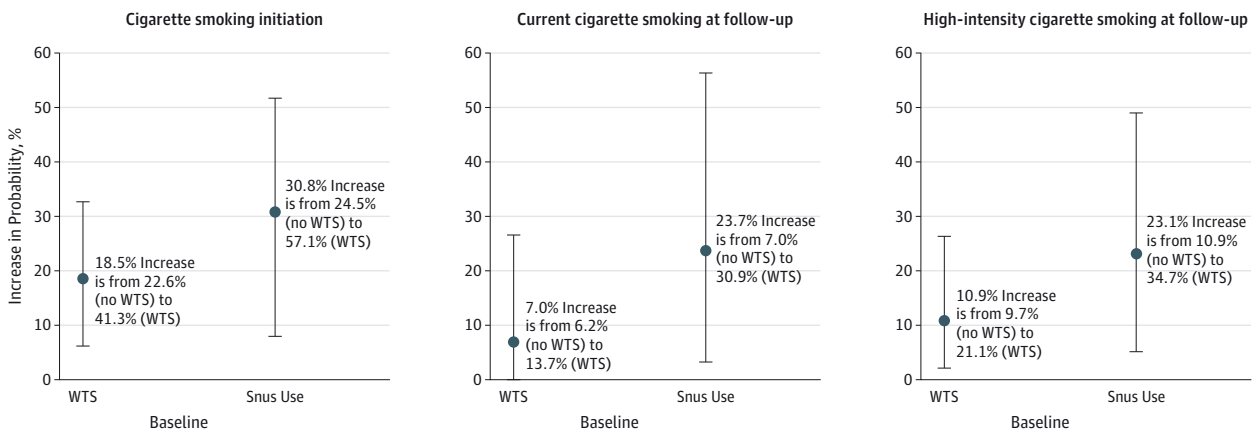
(continued)

Table 3. Multivariable Logistic Regression Analyses of Cigarette Smoking Initiation and Current Cigarette Smoking at Follow-up Among Baseline Non–Cigarette Smokers (continued)

| Covariate | Model, Adjusted Odds Ratio (95% CI) | | | |
|---|---|---|---|---|
| | 1 Cigarette Smoking Initiation | 2 Current Cigarette Smoking at Follow-up | 3 Cigarette Smoking Initiation | 4 Current Cigarette Smoking at Follow-up |
| Urbanicity | | | | |
| Large rural town | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Small town or isolated rural | 1.92 (0.96-3.83) | 3.64 (0.88-14.99) | 2.04 (1.01-4.12) | 4.41 (1.03-18.96) |
| Suburban | 1.09 (0.55-2.16) | 2.72 (0.67-11.09) | 1.21 (0.60-2.42) | 3.52 (0.82-15.04) |
| Urban core | 1.07 (0.62-1.86) | 2.09 (0.60-7.27) | 1.21 (0.69-2.13) | 2.70 (0.75-9.77) |

Abbreviations: NA, not applicable; WTS, water pipe tobacco smoking.

Figure. Predicted Probabilities of Cigarette Smoking Initiation, Current Cigarette Smoking at Follow-up, and High-Intensity Cigarette Smoking at Follow-up




Increases in the probabilities of use are shown for water pipe tobacco smoking (WTS) and snus use. The age group is set at 18 to 20 years, sex at male, race/ethnicity at non-Hispanic white, sensation-seeking quartile at 2, friends' smoking status at yes, parental smoking status at current, maternal educational level at at least some college, and annual parental household income at $50 000 to less than $100 000. The closed circle represents the point estimate of the increase in probability, and the limit lines represent the 95% CI.

To illustrate the population-level implications of our findings, we used the regression models to predict the probabilities of cigarette smoking initiation, current cigarette smoking at follow-up, and high-intensity cigarette smoking at follow-up, varying WTS and snus use at baseline (**Figure**). The predicted probabilities of cigarette smoking initiation were 19.7 (95% CI, 7.3-35.3) percentage points higher for respondents who had smoked water pipe tobacco at baseline than for those who had not and 29.9 (95% CI, 8.3-50.2) percentage points higher for respondents who had used snus at baseline than for those who had not. The predicted probabilities of current cigarette smoking at follow-up were 8.7 (95% CI, 0.4-30.8) percentage points higher for respondents who had smoked water pipe tobacco at baseline than for those who had not and 27.2 (95% CI, 4.2-61.2) percentage points higher for respondents who had used snus at baseline than for those who had not. Finally, the predicted probabilities of high-intensity cigarette smoking at follow-up were 10.7 (95% CI, 2.3-25.8) percentage points higher for respondents who had smoked water pipe tobacco at baseline than for those who had not and 22.2 (95% CI, 3.8-47.3) percentage points higher for respondents who had used snus at baseline than for those who had not.

We observed no significant relationship between baseline WTS and binge drinking at follow-up among baseline non–binge drinking respondents (aOR, 2.03; 95% CI, 0.98-4.20). The adjusted odds of current binge drinking were also not significantly higher for respondents who had used snus at baseline than for those who had not (aOR, 2.23; 95% CI, 0.57-8.68). These results suggest that the longitudinal associations we found between baseline WTS and snus use and subsequent cigarette smoking may not be driven by a higher propensity for risky behavior in general.

## Discussion

In this longitudinal analysis of initial WTS and snus use and subsequent cigarette smoking, we report 2 central findings. First, WTS and snus use among baseline non–cigarette smokers were associated with increased incidence of cigarette smoking, current cigarette smoking, and higher intensity of cigarette smoking at follow-up. Second, although the proportions of baseline non–cigarette smokers who smoked water pipe tobacco (6.8%) and used snus (1.9%) were small, their association with in-

creased likelihood of cigarette smoking supports comprehensive regulation of these alternative products by the FDA.

Our study contributes to a growing body of evidence on the potential for WTS to increase the risk of subsequent cigarette smoking.[25,26] A longitudinal study[16] of first-year college women found that precollege use of water pipe tobacco predicted the initiation and resumption of cigarette smoking. Our study demonstrates a similar finding for other vulnerable populations, namely, adolescents and young adult men.

Water pipe tobacco smoking may increase the risk of subsequent cigarette smoking by exposing youth to nicotine.[27] Water pipe tobacco smokers may transition to cigarette smoking to more effectively satiate nicotine cravings.[28] In addition, WTS introduces youth to the inhalation of a heavily flavored smoke-containing tobacco product in a social setting, which may be reinforced by peer influence. The WTS flavors appeal to youth and may explain why WTS has become increasingly popular. The FDA regulation of water pipe tobacco could address youth appeal by placing limits on characterizing flavors.[29] Regulation by the FDA could also enforce accurate labels that communicate known risks of water pipe tobacco, its ingredients, and by-products from combustion.[30,31]

Our findings on snus use and subsequent cigarette smoking contrast with Swedish studies[32,33] finding that snus use is associated with cigarette smoking cessation in adults. In contrast, snus is marketed in the United States as an alternative to cigarettes when smoking is restricted.[34] The US tobacco companies also promoted snus to new tobacco users with flavors that appeal to youth, low-nicotine content, and distribution of free samples.[6] Therefore, marketing of snus in the United States may anticipate either the transition to cigarette smoking or dual cigarette and snus use. Although overall sales of snus have recently declined in the United States, snus and other smokeless tobacco products remain popular among young rural male tobacco users.[35] The FDA regulates snus less stringently than other smokeless tobacco products.[36] The FDA could extend authority by banning free samples and set a minimum pack size. In addition to possible regulation, the FDA is developing a new ad campaign on smokeless tobacco products (to be launched in 2015) that focuses on rural boys 12 to 17 years old. Our findings suggest that the FDA ad campaign may also reduce subsequent cigarette smoking.

This longitudinal study has several strengths. It demonstrates associations between the use of 2 alternative tobacco products and subsequent cigarette smoking, addresses cigarette smoking initiation and intensity, and considers possible explanations. We also note important limitations. First, we cannot establish that WTS and snus use caused subsequent cigarette smoking. Respondents who smoked water pipe tobacco or used snus at baseline may have also used other tobacco products. In addition, we cannot establish the amount of time that elapsed between initial WTS and snus use and subsequent cigarette smoking. Second, we did not account for secular trends in cigarette smoking initiation, which may have differed between youth who did and did not smoke water pipe tobacco and use snus. Third, we may have inadvertently included past cigarette smokers in the sample of baseline non–cigarette smokers if these respondents had failed to recall cigarette use. Fourth, socioeconomic status was determined by maternal educational level but not paternal education level. Fifth, we observed differential attrition of racial/ethnic minorities, high sensation seekers, respondents with friends or parents who smoked, and respondents who had smoked water pipe tobacco and used snus.

Three possible explanations may have led to our findings. First, water pipe tobacco and snus may serve as gateway tobacco products to cigarette smoking. We found that WTS and snus use were associated with increased incidence of cigarette smoking initiation and increased incidence and intensity of cigarette smoking at follow-up. Yet, we do not know if baseline non-cigarette smoking respondents who subsequently began cigarette smoking at follow-up would have done so even in the absence of earlier WTS and snus use. In addition, we do not know if baseline non-cigarette smoking respondents who had smoked water pipe tobacco or used snus had also used other tobacco products, such as cigars or electronic cigarettes. Second, some respondents may have an underlying propensity to use tobacco that is not specific to any one tobacco product.[37] The presence of a common propensity for tobacco use may help to explain why some adolescents and young adults who smoke cigarettes concurrently use other tobacco products.[2] Third, an underlying tendency to deviance may lead to multiple problem behaviors.[38] We found that problem drinking did not increase the likelihood of subsequent cigarette smoking. Furthermore, engagement in 2 problem behaviors, WTS and snus use, did not increase the likelihood of problem drinking, although we did not consider other problem behaviors (eg, illicit drug use).

## Conclusions

In conclusion, our study demonstrates that WTS and snus use among non-cigarette smoking adolescents and young adults were longitudinally associated with subsequent cigarette smoking. Yet, water pipe tobacco remains largely unregulated by the FDA, and snus is less regulated than other smokeless tobacco. Even if regulation proposed in 2013 becomes final, US tobacco companies may legally contest the new rule, which could delay its implementation.[39,40] The success of FDA tobacco regulatory control policies will depend, in part, on their ability to reduce the use of alternative tobacco products that may lead to subsequent cigarette smoking.

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